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FOR

MONITORING A SEMICONDUCTOR LASER UTILIZING AN INCORPORATED BEAM SPLITTER DEVICE

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MONITORING A SEMICONDUCTOR LASER UTILIZING AN INCORPORATED BEAM SPLITTER DEVICE

FIELD OF INVENTION

The present invention relates to the field of optical components. More specifically, the present invention relates to monitoring a semiconductor laser utilizing a beam splitter type device.

BACKGROUND OF THE INVENTION

The widespread deployment of high-speed networking and communications equipment has produced a large demand for various types of networking communication components and subsystems. Included among these, are packages, which are often referred to as photonic packages.

An important aspect of optical components, such as optical components used in telecommunications and data communications technology (i.e., lightwave communications), is the monitoring of a semiconductor light source within a photonic package. Often times, the semiconductor light source may be in the form of a semiconductor laser. Monitoring of the semiconductor light source, such as the semiconductor laser, is important because light emitted from the semiconductor light source carries data. In order to facilitate monitoring of the semiconductor laser, often times, the semiconductor laser is manufactured in such a way as to emit light in two directions. The two directions that the semiconductor laser may emit light are known as a front facet and a back facet.

Light emitted from the front facet of the semiconductor laser is commonly coupled to an optical fiber for data transmission. Light emitted from the back facet is commonly provided to a photodiode for monitoring. Because light emitted from the back facet is a percentage of the light emitted from the front facet, monitoring the light emitted from the back facet provides information regarding light emitted from the front facet. This monitoring is commonly referred to as back-facet monitoring (BFM). Accordingly, various information regarding light being provided to the optical fiber for transmission may be determined from the photodiode monitoring light emitted from the back facet.

Conventional photonic packages typically include a case, or housing, within which electrical and optical components, such as the semiconductor laser and the photodiode, are enclosed. Such a housing provides physical protection for the components therein, and provides thermal conductivity so that heat may be dissipated from the components disposed within the case. The number of components may be numerous. However, a requirement of the housing is that the housing be of a small form factor. Accordingly, in order to have the components within a housing of a small form factor, placement of the components is an important aspect of the photonic package.

Placement of the components may be determined by one component's operation relative to another's. For example, as described above, a component, such as a semiconductor light source, that operates to provide light-based signals is placed in such a manner as to be optically coupled to another component, such as an optical fiber, that operates to optically transmit light-based signals. Accordingly,

placement of the photodetector is opposite the side of the semiconductor light source coupled to the optical fiber.

As the sophistication of the photonic packages increases, the number of components may increase as well. However, the form factor of the housing of the photonic package continues to become smaller. As a result, placement of the photodetector in the light path opposite the optical fiber side of the semiconductor light source becomes increasingly difficult due to various components included in the housing.

Thus, an improved approach for monitoring a semiconductor light source within a photonic package is desired.

BRIEF DESCRIPTION OF DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:

FIGURE 1 illustrates an exemplary photonic package with which an embodiment of the present invention may be practiced;

FIGURE 2 illustrates a detail area of one embodiment of the present invention;

FIGURE 3 illustrates monitoring of a semiconductor light source utilizing a beamsplitter within a photonic package, in accordance with an alternate embodiment of the present invention; and

FIGURE 4 illustrates operational flow for monitoring of a semiconductor light source utilizing a beam splitter cube within a photonic package, in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention facilitates monitoring of a semiconductor light source utilizing a beamsplitter within a photonic package. These and other advantages will be evident from the disclosure to follow.

In the following description, various aspects of the invention will be described. However, it will be apparent to those skilled in the art that the invention may be practiced with only some or all described aspects. For purposes of explanation, specific numbers, materials, and configurations are set forth in order to provide a thorough understanding of the invention. However, it will also be apparent to one skilled in the art that the invention may be practiced without specific details. In other instances, well-known features are omitted or simplified in order not to obscure the invention. Similarly, for purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the invention. Nevertheless, the invention may be practiced without specific details. In other instances, well-known features are omitted or simplified in order not to obscure the invention. Furthermore, it is understood that the various embodiments shown in the figures are illustrative representations and are not necessarily drawn to scale.

References throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, material, or characteristic described in connection with the embodiment, is included in at least one embodiment of the invention. Thus, the appearances of the phrase “in one embodiment” of “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment or invention. Furthermore,

the particular features, structures, materials, or characteristics may be combined in any suitable manner in one or more embodiments.

For the purposes of describing the invention, lightwaves will be illustrated as straight lines. However, one skilled in the relevant art will appreciate that lightwaves may behave as waves or particles. Additionally, certain established principles of physics will not be described in detail, in particular, derivations of equations such as those describing the behavior of semiconductors and the like will not be described in detail. However, relevant equations will be described but not derived.

Accordingly, the concept of data carried by lightwaves will not be described in detail. However, for the purposes of the invention, the concept of utilizing different wavelengths of lightwaves to carry different data may be referred to in describing the invention.

FIGURE 1 illustrates an exemplary photonic package with which an embodiment of the present invention may be practiced. Illustrated in **FIG. 1**, is a perspective view of a photonic package **100**. The photonic package **100** includes a first substrate **105** upon which various components are mounted. The various components may include components such as, but not limited to, a second substrate **106**, an integrated circuit **107** mounted on the second substrate **106**, and a representation of an optical fiber **108**. Additionally, the photonic package **100** includes a photodetector **110** and a semiconductor light source **111**, both mounted on the first substrate **105**. The semiconductor light source **111**, in particular, has a front facet **112**. In one embodiment, a first lens **113** is optically coupled to the front facet **112** of the semiconductor light source **111**, a beam splitter cube (BSC) **114** is

optically coupled to the first lens **113**, and a second lens **115** is optically coupled to the BSC **114** and the optical fiber **108**. As illustrated in **FIG. 1**, the photonic package **100** may be included in a housing **120** to provide physical protection for the components therein.

Illustrated in **FIG. 1**, the second substrate **105** may provide an additional platform, upon which, various components, such as, but not limited to, the integrated circuit **107**, may be mounted. The integrated circuit **107** may be a thermally sensitive device, such as, but not limited to, a thermistor. The first and second substrates **105-106** and the integrated circuit **107** are known in the art, and accordingly, will not be further described. However, as alluded to earlier, it should be appreciated that the components, such as, but not limited to, the first and second substrates **105-106** and the integrated circuit **107**, are illustrated to provide an example of limited space within a typical photonic package.

The semiconductor light source **111** provides light via the front facet **112** to the optical fiber **108**. The semiconductor light source **111** may be a semiconductor laser, such as, but not limited to, a gallium arsenide (GaAs) type laser. The semiconductor light source is known in the art, and accordingly, will not be described in further detail.

Illustrated in **FIG. 1**, in one embodiment, the photodetector **110** is advantageously disposed in a substantially perpendicular manner to an optical path of the semiconductor light source **111**, where the optical path may be a path that a beam of light would travel from the semiconductor light source **111** to the optical fiber **108**. Additionally, illustrated in **FIG. 2**, the photodetector **110** is disposed on a

tracing **125** to facilitate transmission of electrical signals output by the photodetector **110** responsive to received light to a processor (not shown). The photodetector **110** is adapted to produce an electrical signal responsive to received light based at least upon properties of the photodetector **110** such as, but not limited to, spectral responsivity, external quantum efficiency, noise, response time, dark current, and junction capacitance. The photodetector **110** may be a photodiode, such as, but not limited to, p-layer, intrinsic layer, and n-layer (p-i-n) junction photodiode, an Schottky photodiode, or an avalanche photodetector. As will be described in further detail below, disposing the photodetector **110** as shown facilitates monitoring of the semiconductor light source **111** away from the limited space behind the semiconductor light source **111**.

Additionally, in the embodiment illustrated in **FIG. 1**, the first lens **113** facilitates modification of light emitted from the semiconductor light source **111**. The second lens **115** facilitates modification further modification of light emitted from the semiconductor light source **111** to be provided to the optical fiber **108**. The lenses **113 & 115** may be of any type to modify light based at least upon principles of Hermite-Gaussian beam (i.e., laser light). The lenses **113 & 115** may be made of any type of a high quality glass, such as, but not limited to, BK7 glass. Focusing of the lenses **113 & 115** to modify light is known, and accordingly, will not be described. Additionally, in the illustrated embodiment of **FIG. 1**, two lenses **113 & 115** are shown, however, it should be appreciated by those skilled in the art that the first lens may be omitted (i.e., non-collimated light) within the spirit and scope of the

present invention. However, for the purpose describing the present invention, the desired modification of light by the lenses **113 & 115** will be described.

Utilization of the BSC **114** with the semiconductor light source **111**, the first and second lenses **113 & 115**, and the photodetector **110**, advantageously facilitates selective placement of the photodetector **110**.

For ease of understanding the present invention, detail area **130**, including the semiconductor light source **111**, the first and second lenses **113 & 115**, the optical fiber **108**, the photodetector **110**, and the BSC **114**, will be described in further detail below.

Before describing these elements in further detail, it should be noted that while for ease of explanation, the present invention is being described in the context of photonic packages, however, based on the description to follow, a person skilled in the art will appreciated that the present invention may be adapted for other applications besides photonic packages.

FIGURE 2 illustrates a detail area of one embodiment of the present invention. Illustrated in **FIG. 2**, a top view of detail area **130**, including the semiconductor light source **111**, the first and second lenses **113-114**, the optical fiber **108**, the photodetector **110**, and the BSC **114**, is shown in block diagram form.

As previously described in **FIG. 1**, the semiconductor light source **111** is optically coupled to the first lens **113**, the first lens is **113** optically coupled to the BSC **114**, the BSC **114** is optically coupled to the photodetector **110** and the second lens **115**, and the second lens **115** is optically coupled to the optical fiber **108**.

In one embodiment, the BSC **114** is comprised of a first right angle prism **210** and a second right angle prism **211** having the two right angle prisms **210-211** adhesively joined at the hypotenuse **212**. The BSC **114** may be made of a high quality glass, such as, but not limited to, BK7A glass. Additionally, the hypotenuse **212** may have a coating to reflect a percentage of light, such as, but not limited to, a multilayer dielectric material. The multilayer dielectric material may be based at least upon the percentage of light to be reflected. An example of a BSC may be a laser-line nonpolarizing dielectric cube beamsplitter available from Melles Griot of Irvine, California.

Additionally, shown in **FIG. 2**, the photodetector **110** has a window **220** to receive light for monitoring the semiconductor light source **111**. As alluded to earlier, the photodetector **110** may be advantageously placed in various manners, in accordance with various embodiments of the present invention.

In the embodiment illustrated in **FIG. 2**, the semiconductor light source **111** provides a first light beam **230** output from the front facet **112** to the first lens **113**. As alluded to earlier, the first light **230** may be any type of coherent light, such as, but not limited to, laser light that has data encoded thereon. The first lens **113** may be utilized to modify the first light beam **230** resulting in a modified first light beam **231**. The modification may be in the form of collimating the first light beam **230** (i.e., straightening the light beam). The properties of the first light beam output **230** and the modified first light beam **231** may be substantially identical because the first lens **113** does not negatively impact the first light beam **230** (i.e., integrity, power, encoded data, and the like are maintained).

The modified first light beam **231** propagates through the first lens **113** onto the BSC **114**. Modified first light beam **231** incidences on the hypotenuse **212** of the BSC **114** having the dielectric coating. Based at least upon the principles of frustrated total internal reflection (FTIR) and the dielectric coatings at the hypotenuse **212**, a first predetermined percentage of the modified first light beam **231** is split by the BSC **114**, in particular, the hypotenuse **212**, resulting in a first split output **232** from the BSC **114**. Additionally, based at least upon the principles of FTIR and the dielectric coatings at the hypotenuse **212**, a second predetermined percentage of the collimated light **231** is transmitted through the BSC **114**, in particular, the hypotenuse **212**, resulting in a second split output **233** from the BSC **114**.

Due to the characteristics of splitting the modified first light beam **231** by BSC **114**, the BSC **114** has a negative impact on the modified first light beam **231**, such as, on the encoded data included in the first light beam output **230**. However, the negative impact may be within a predetermined limited threshold. That is, the first percentage for the first split output **232** may be small relative to the first light beam output **230**, such as, but not limited to a 2%. Accordingly, 2% of the first modified first light beam **231** makes up the first split output **232** from the BSC **114**, and 98% of the modified first light beam **231** makes up the second split output **233** from the BSC **114**. The predetermined limited threshold may be based at least upon properties of the first light beam output **230**, such as but not limited to, signal tolerance, and accordingly, smaller percentages may be split. Additionally, the predetermined limited threshold may be based at least upon properties of the

photodetector **110**, such as but not limited to, sensitivity of the photodetector **110**. Accordingly, alternatively, based at least upon the predetermined limited threshold of the light beam, the first percentage for the first split output **232** may be large relative to the first light beam output **230**.

First split output **232** from the BSC **114** is shown directed towards the window **220** of the photodetector **110**, where the photodetector **110** receives the first split output **232** to facilitate monitoring of the semiconductor light source **111** (i.e., properties of first light beam output **230**). As alluded to earlier, the photodetector **110** converts the first split output **232** into electrical energy (i.e., electrical signals) that may be provided to the processor, wherein the electrical signals may be compared to characterization data. The characterization data may relate electrical signals from the photodetector **110** produced by the first split output **232** received by the photodetector **110** of the first light beam output **230** from the semiconductor light source **111**. For example, referring to **FIG. 2**, characterization data may be produced by having several data points corresponding to power of light of the first light beam output **230** from the front facet **112** as compared to the power of light of the first split output **232**, thereby calibrating the photodetector **110** to properly monitor the semiconductor light source **111**.

Second split output **233** from the BSC **114** continues in the original optical path towards the second focusing lens **115**. The second lens **115** may be utilized to modify the second split output **233** resulting in a modified second split light beam **234**. The modification may be in the form of focusing second split output **233** to facilitate efficient optical coupling of the optical fiber **108**. The properties of the

second split output **233** and the modified second split light beam **234** may be substantially identical because the second lens **113** does not negatively impact the first light beam **230** (i.e., integrity, power, encoded data, and the like are maintained).

As a result, monitoring of a semiconductor light source utilizing a beamsplitter within a photonic package is facilitated.

In one embodiment, the optical fiber **130** may be of a type that is fabricated with an integrated lens end (not shown). Accordingly, the second lens may not be present because the second split output **233** may be focused to the optical fiber **108** by the integrated lens end of the optical fiber **108**.

In one embodiment, the semiconductor light source **111** may be of a type that provides a collimated light beam. Accordingly, the first lens may not be present because the first light beam **230** output from the front face **112** may already be collimated.

In one embodiment, the semiconductor light source of the type that provides a collimated light beam and the optical fiber of the type that is fabricated with an integrated lens end may be combined. Accordingly, the first and second lens **113 & 115** may be not present.

In one embodiment, first split output **232** from the BSC **114** may be indirectly monitored within the housing **120** of the photonic package **100**. An example of indirect monitoring may be found in co-pending U.S. Pat. Application No. <__/___,___>, titled "INDIRECT MONITORING OF SEMICONDUCTOR LIGHT SOURCE WITHIN A PHOTONIC PACKAGE", contemporaneously filed and having

at least partial common inventorship with the present application. The application is hereby fully incorporated by reference.

FIGURE 3 illustrates monitoring of a semiconductor light source utilizing a beamsplitter within a photonic package, in accordance with an alternate embodiment of the present invention. Illustrated in **FIG. 3**, is a perspective view of a photonic package **300** incorporating the present invention. The photonic package **300** includes a substrate **302** upon which various components may be mounted. In the illustrated embodiment, mounted on the substrate **302** is a semiconductor light source **305**, however, as described previously, it should be appreciated that commonly, numerous components may be mounted on the substrate **302**. The semiconductor light source **305**, in particular, has a front facet **307**. In the embodiment illustrated in **FIG. 3**, a single lens **307** is optically coupled to the front facet **306** of the semiconductor light source **305**. Additionally, illustrated in **FIG. 3**, a first polarizing element **310** is optically coupled to the single lens **307**, and a light isolator element **311** is optically coupled to the first polarizing element **310**. Additionally, a second polarizing element **312** is optically coupled to the light isolator element **311**, and a beam splitter cube (BSC) **313** is optically coupled to the second polarizing element **312**, which in turn, may be coupled to an optical fiber (not shown).

In the embodiment illustrated in **FIG. 3**, a photodetector **320** is advantageously disposed in such a manner as to monitor light from the from the semiconductor light source **305** away from the optical path of light. The photodetector **320** has a window **321** to receive light for monitoring the

semiconductor light source **305**. In one embodiment, the photodetector **320** is disposed in a substantially perpendicular manner, as shown. Furthermore, as described previously with respect to **FIG. 1**, the photonic package **300** may be included in a housing (not shown).

Illustrated in **FIG. 3**, a first light beam **330** from the semiconductor light source **305**, in particular, the front facet **306**, is collimated by the single lens **307**, and proceeds to the first polarizing element **307**. Generally, the first polarizing element **310** polarizes the first light beam **330**, the light isolator element **311** rotates the first light beam **330** a predetermined angle, and the first light beam **330** is polarized by the second polarizing element **312** to provide the first light beam **330** to an optical fiber (not shown). However, in the illustrated embodiment of the present invention of **FIG. 3**, after the second polarizing element **312**, the first light beam **330** is provided to the BSC **313**. The BSC **313** creates a first split output **331** that negatively impacts data encoded on the first light beam **330** within a predetermined limited threshold. The first split output **331** is received by the photodetector **320**, in particular, the window **321**. A second split output **332** is provided from the BSC **313** to an optical fiber (not shown).

As previously described, the semiconductor light source **305** may be a semiconductor laser, such as, but not limited to, a gallium arsenide (GaAs) type laser. The semiconductor light source is known in the art, and accordingly, will not be described in further detail. The single lens **307** may be of any type, such as, but not limited to, a spherical lens mad of high quality glass.

In the illustrated embodiment of **FIG. 3**, the first polarizing element **310**, the light isolator element **311**, and the second polarizing element **312** may facilitate optical isolation, and may be referred to as an optical isolator type structure. Generally, an optical isolator type structure facilitates prevention of backward reflected light that may affect the integrity of signal from a semiconductor light source. Accordingly, the first and second polarizing elements **310 & 312** may be of any type, such as, but not limited to, polarizer plates. The light isolator element **311** may be of any type to provide a Faraday effect, such as, but not limited to, bismuth garnet that may be affected by magnetic fields. However, in the illustrated embodiment of the present invention of **FIG. 3**, the optical isolator type structure incorporates the BSC **313**.

As previously described, the BSC **313** may be, in one embodiment, comprised of a first right angle prism and a second right angle prism having the two right angle prisms adhesively joined at the hypotenuse. The BSC **313** may be made of a high quality glass, such as, but not limited to, BK7A glass. Additionally, the hypotenuse has a coating to reflect a percentage of light, such as, but not limited to, a multilayer dielectric material. The multilayer dielectric material may be based at least upon the percentage of light to be reflected. An example of a BSC may be a laser-line nonpolarizing dielectric cube beamsplitter available from Melles Griot of Irvine, California.

As previously described, the photodetector **320** is disposed on a tracing (not shown) to facilitate transmission of electrical signals output by the photodetector **320** responsive to received light to a processor (not shown), thereby calibrating the

photodetector **320** to properly monitor the semiconductor light source **305**. Here again, the photodetector **320** is adapted to produce an electrical signal responsive to received light based at least upon properties of the photodetector **320** such as, but not limited to, spectral responsivity, external quantum efficiency, noise, response time, dark current, and junction capacitance. The photodetector **320** may be a photodiode, such as, but not limited to, p-layer, intrinsic layer, and n-layer (p-i-n) junction photodiode, an Schottky photodiode, or an avalanche photodetector.

It should be noted that while for ease of explanation, the present invention is being described in the context of light beam having data encoded thereon, however, based on the description to follow, those skilled in the art will appreciate that the present invention may be adapted to other applications besides light beam having data encoded thereon, where light monitoring is required. For example, a continuous wave laser module, which require light monitoring.

In one embodiment, the BSC **313** illustrated in **FIG. 3** may be of the polarizing type, where the BSC **313** is disposed in such a manner as to receive the first light beam **330** directly from the light isolator device **311**. The polarizing type BSC creates the first split output **331** of the first light beam **330** to be received by the photodetector **320**.

In one embodiment, the light isolator element **311** illustrated in **FIG. 3**, may be cleaved to facilitate beam splitting by the rotating element **311**. The cleaved light isolator element **311** may be comprised of a first right angle light isolator element and a second right angle light isolator element, having the two right angle prisms adhesively joined at the hypotenuse similar to the BSC previously described. thus,

the BSC of **FIG. 3**, may be omitted, and instead, the light isolator element **311** may create the first split output **331**. The first split output **331** may be created by the cleaved light isolator element by the predetermined application of magnetic fields. Accordingly, for this embodiment, the beam splitter may be made of any type to provide a Faraday effect, such as, but not limited to, bismuth garnet that may be affected by magnetic fields.

In one embodiment, an electro-optic (EO) modulator incorporates the BSC **114 & 313**, where the EO provides information on a light beam, such as, the first light beam output **230 & 330**. Accordingly, an EO element that is capable of varying the light beam at high speeds in a controlled manner, such as, but not limited to, a synthetic magnetic crystal, may be cleaved, as previously described. An example of an EO element may be a crystal, such as, but not limited to, yittrium-iron garnet type. . Except for the novel aspects of integrating beam splitters within the an EO, EOs are known, and accordingly will not be described further.

As a result, monitoring of a semiconductor light source is improved by facilitating utilizing a beamsplitter within a photonic package. Additionally, an optical isolator type structure advantageously incorporates the beamsplitter.

As alluded to earlier, in yet another embodiment, the first split output **331** from the BSC **313** may be indirectly monitored within the housing (not shown) of the photonic package **300**. An example of indirect monitoring may be found in co-pending U.S. Pat. Application No. <__/___,___>, titled "INDIRECT MONITORING OF SEMICONDUCTOR LIGHT SOURCE WITHIN A PHOTONIC PACKAGE",

contemporaneously filed and having at least partial common inventorship with the present application. The application is hereby fully incorporated by reference.

FIGURE 4 illustrates operational flow for monitoring of a semiconductor light source utilizing a beam splitter cube within a photonic package, in accordance with one embodiment of the present invention. At block **402**, a first light beam output is generated by a semiconductor light source that is disposed within a housing. The first light beam output, having data encoded thereon, is provided to a beam splitter cube (BSC) that is also disposed within the housing, at block **405**. The BSC, having a light beam characteristic that negatively impacts the encoding of the data in the first light beam, creates a first split output of the first light beam output, at block **410**. The negative impact on the encoding of the data in the first light beam is within a predetermined limited threshold.

At block **415**, the first split output is received at a photodetector disposed within the housing. The photodetector is adapted to determine properties of the first split output notwithstanding the first split output being created in the limited impact manner.

Thus, it can be seen from the above descriptions, a novel method and apparatus for monitoring of a semiconductor light source utilizing a beamsplitter within a photonic package, has been described.

The above description of illustrated embodiments of the invention, including what is described in the Abstract, is not intended to be exhaustive or to limit the invention to the precise forms disclosed. While specific embodiments of, and examples for, the present invention are described herein for illustrative purposes,

various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. Thus, the description is to be regarded as illustrative instead of restrictive on the invention.